

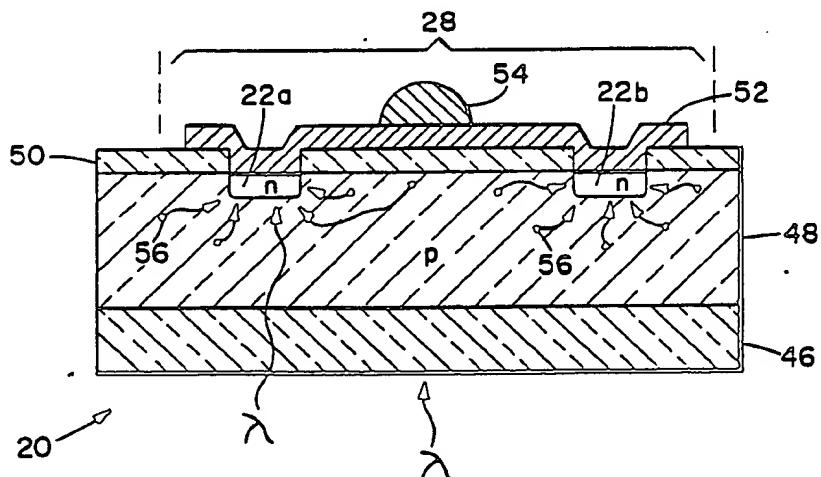


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(54) Title: REDUCED AREA PHOTODIODE JUNCTION



(57) Abstract

The pn-junction of a photodiode (20) is reduced in area to minimize the capacitance associated with the junction and increase the diode impedance. The reduction in junction area, and also the junction capacitance, is accomplished by subdividing the junction into a plurality of smaller junctions, or subjunctions (22a, 22b). The total area of the subjunctions is less than the area of a unitary, continuous area junction required for a corresponding desired optical area. The shape of each subjunction and the spacing between adjacent subjunctions is selected such that the lateral collection region around the periphery of each of the subjunctions overlap one another yielding an effective optical area of approximately the same size as a device having a single unitary, larger junction. Each of the plurality of subjunctions may be conductively coupled one to another by a layer of metallization (52) which is deposited such that it contacts each of the subjunctions. Each of the subjunctions may, alternatively, be conductively coupled one to another by being physically in contact.

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1

REDUCED AREA PHOTODIODE JUNCTION

FIELD OF THE INVENTION

5 The present invention relates generally to photodiodes and, in particular, relates to a photodiode having a pn-junction of reduced area.

BACKGROUND OF THE INVENTION

10 Photodetectors, such as photodiodes, are typically comprised of a volume of active photodetecting semiconductor material having a diode junction formed within a surface of the material. The junction typically collects charge carriers which are induced in the active region by the absorption of radiation. The junction collects carriers generated beneath the junction and also carriers generated outside the junction periphery. This collection process is typically facilitated by the diffusion of the carriers through the active region and into the junction. Due to the collection of photocarriers from the periphery of the junction an optically sensitive region associated with the junction extends laterally outward from the junction such that the optically sensitive region is generally larger than the junction area itself. The outermost extent of this lateral, or peripheral, collection region is a variable, and depends on the temperature of the semiconductor material, the doping concentration of the semiconductor material and other factors.

1 In general, it is desirable to make the junction area
as small as possible to reduce the capacitance
associated with the junction and also to increase the
impedance of the junction. As can be appreciated, this
5 reduction in junction capacitance results in an
increased operating speed of the photodiode. Such an
increase in speed may be especially desirable in focal
plane array detectors wherein a plurality of
10 pn-junctions, or photodiodes, are formed as a regular
two-dimensional array over the surface of a layer of
radiation-absorbing semiconductor material. The
photodetecting material may be a layer of
mercury-cadmium-telluride (HgCdTe) which is grown upon
15 a cadmium-telluride (CdTe) substrate. In such a device
the incident radiation to be detected may enter the
device through the substantially transparent substrate,
the radiation passing through the substrate and into
the overlying layer of HgCdTe where the radiation is
absorbed, thereby generating charge carriers. These
20 charge carriers diffuse through the active HgCdTe layer
until they are captured by one of the plurality of
diode junctions formed upon an upper surface of the
HgCdTe layer. Each of the photodiode junctions is
coupled to detector circuitry which may scan the array
25 of photodiodes in a row or column type fashion at a
relatively high scanning rate. An increase in
impedance, or diode resistance, is desirable in that it
tends to increase the signal-to-noise ratio of the
photodiode.

30

However, a problem is created when the area of the
junction is decreased in that the aforementioned
lateral collection area is also correspondingly

1 decreased, resulting in an overall decrease in the total volume of the diode photodetecting region and a consequent reduction in diode output signal magnitude.

5 SUMMARY OF THE INVENTION

The foregoing problem is overcome and other advantages are realized by a photodiode constructed in accordance with the invention.

10 In one illustrative embodiment of the invention, the pn-junction area of a photodiode is reduced in area to minimize the capacitance associated with the junction and increase the diode impedance. The reduction in junction area is accomplished by subdividing the junction into a plurality of smaller junctions, or subjunctions, the total area of which is less than the area of a unitary junction required for a corresponding desired optical area. The shape of each subjunction and the spacing between adjacent subjunctions is selected such that the lateral collection region around the periphery of each of the subjunctions overlap one another yielding an effective optical area of approximately the same size as a device of the prior art having a single unitary, larger junction. Each of the plurality of subjunctions may be conductively coupled one to another by a layer of metallization which is deposited such that it contacts each of the subjunctions.

15 20 25 30 In accordance with another embodiment of the invention, a desired optical area is achieved by a unitary pn-junction which is reduced in area over a

1 corresponding junction of the prior art while yet
providing for the collection of charge carriers from an
approximately equally sized region. The reduced area
5 unitary junction may be constructed as a plurality of
physically interconnected subjunctions each of which
has a predetermined shape and a spacing one from the
other such that the lateral collection area surrounding
each subjunction overlaps, thereby yielding an active
area of a desired size.

10

In accordance with a method of the invention the
capacitance of a photodiode pn-junction is reduced by
determining a required size of an optical area for a
given application, determining the area size of a
15 continuous, unitary junction that will provide the
determined optical area and subdividing the determined
area of the junction into a plurality of smaller
subjunctions each of which has a shape and a spacing
one from another for defining a continuous lateral
20 charge carrier collection area which is substantially
equal to the predetermined size of the optical area.
Inasmuch as the total area of the subjunctions is less
than that of the continuous junction, for the
determined optical area, the capacitance of the
25 resulting junction is decreased.

BRIEF DESCRIPTION OF THE DRAWINGS

30 The following aspects of the invention will become more
apparent in conjunction with the following detailed
description of the invention taken in conjunction with
the accompanying drawings wherein:

1 Fig. 1 shows a top view of a conventional photodiode having an optical area and a unitary, relatively large junction area formed therein;

5 Fig. 2 is a cross-sectional view of the photodiode of Fig. 1 taken along the line 2-2;

10 Fig. 3 shows a top view of a photodiode junction having, in accordance with one embodiment of the invention, a pair of side by side disposed elongated subjunctions having overlapping optical areas;

15 Fig. 4 shows a top view of four substantially circular subjunctions which are disposed such that their respective peripheral collection areas overlap to form an optical area having an area substantially equal to that to the device of Fig. 1;

20 Fig. 5 shows a top view of a photodiode having a junction which, in accordance with another embodiment of the invention, is comprised of substantially linear subjunctions interconnected in a rectangular fashion for defining an optical area of a size substantially equal to the photodiode of Fig. 1;

25 Fig. 6 shows a top view of another embodiment of a unitary, reduced area photodiode junction having an associated optical area which is similar in size to the device in Fig. 1;

30 Fig. 7 is a cross-sectional view of a photodiode, taken along the line 7-7 of Fig. 2, showing subjunctions formed within a layer of photodetecting material and a

1 layer of metallization which conductively couples the
subjunctions one to another; and

5 Fig. 8 is a top view of a portion of an array of
photodiodes, each of the photodiodes being comprised of
a plurality of subjunctions.

DETAILED DESCRIPTION OF THE INVENTION

10 Referring now to Figs. 1 and 2 there is shown a
conventional photodiode 10 having a pn-junction 12 and
a corresponding surrounding optical area 14. The size
of the optical area 14 is related to the area of the
junction area itself and also to the furthest extent of
15 a lateral collection of charge carriers by the junction
around the periphery of the junction. The junction
also collects charge carriers generated in a region of
active material which is below the junction area 12.
The actual size of the optical area 14 is related to
20 several factors, such as the doping concentration of
the active semiconductor material, the temperature of
the semiconductor material and other factors.

25 As can be seen in Fig. 2 the photodiode 10 may be
comprised of a substrate 16 having a layer of
photodetecting semiconductor material 18 deposited
thereon. The layer 18 may be formed by a number of
well known methods, such as by vapor or liquid phase
30 deposition upon the supporting substrate 16. The
substrate 16 may be comprised of CdTe which is
substantially transparent to wavelengths of radiation
of interest. The layer 18 may be comprised of HgCdTe
which absorbs these wavelengths of interest thereby

1 generating photocarriers 20 which are collected by the
junction 12. This collection is typically due to the
charge carriers, which may be holes or electrons
depending on a type of doping impurity within the layer
5 18, diffusing to the oppositely doped junction. Not
shown in Fig. 2 is the interconnection between the
junction 12 and detector circuitry which detects the
presence of these collected charge carriers to generate
10 a photodiode output signal. In order to form a
pn-junction the layer 18 is typically doped with a p or
an n type of dopant and the junction is doped with a
dopant having the opposite electrical characteristic.
In Fig. 2 it can be seen that the layer 18 is doped
15 with a p type dopant and the junction 12 is doped with
an n type dopant.

As can also be seen in Fig. 2, the optical area 14
extends beyond the periphery of the junction 12, this
being due to the lateral diffusion of the charge
20 carriers 20 along the periphery of the junction 12.
Thus, the photoactive detecting region has a volume
which includes not only the volume of the layer 18
immediately beneath the junction 12 but also a portion
25 of material surrounding the periphery of the junction
12. The outermost extent of the optical area 14, as
has been stated, is dependent upon several factors such
as the doping concentration of the layer 18 and the
junction 12 and also upon the temperature of the
semiconductor material within the layer 18.

30 As has been previously stated, in order to reduce the
capacitance associated with the pn-junction and also to
increase the impedance of the junction it is desirable

1 to minimize the surface area of the junction 12. However, as this surface area of the junction 12 is
decreased the associated optical area 14 is
5 correspondingly decreased, thereby resulting in a
reduced electrical signal being generated by the
photodetector.

Referring now to Fig. 3 there is shown a portion of a
10 diode 20 having, in accordance with one embodiment of
the invention, a pair of subjunctions 22a and 22b which
have a predetermined shape and spacing therebetween
such that an optical area 24a and 24b, respectively, of
each has an overlap region 26. The optical area 24 of
15 each subjunction 22 is in part determined by the
lateral collection of photocarriers from the periphery
of each of the subjunctions 22. Thus, this overlap
region 26 is a region where the optical area 24 of each
subjunction 22 overlaps such that a charge carrier
generated within the overlap region 26 may diffuse to
20 either of the subjunctions 22a or 22b. This overlap
between subjunctions 22a and 22b results in an
effective total optical area 28 which is the sum of
both optical areas 24a and 24b minus the area of the
overlap region 26. Thus, the optical area 28 may be
25 substantially equal to the optical area 14 of Fig. 1.
However, the total of the areas of subjunctions 22a
and 22b is less than the junction area 12 of Fig. 1.
This reduction in overall junction area beneficially
reduces the capacitance associated with the junction
30 and increases the impedance of the junction. This
decrease in junction capacitance results in, for
example, the photodiode 20 having a faster response
time to incident radiation than the photodiode 10 of

1 Fig. 1. The increase in junction impedance results in
the diode 20 having a higher signal-to-noise ratio than
the diode 10 of Fig. 1.

5 The elongated shape of each of the subjunctions 22a and
22b is but one possible shape for achieving this
beneficial reduction in junction area. Referring now
to Fig. 4 there can be seen a diode 30 which is
10 comprised of four substantially circular subjunctions
32a through 32d, each of the junctions 32 having an
active optical area 34a through 34d. The spacing
between subjunctions 32 is such that the individual
optical areas 34 overlap to form an overall optical
15 area 36 which may be similar in size to the optical
area 14 of Fig. 1. However, the total junction area,
which is the sum of the individual areas of the
subjunctions 32, can be seen to be substantially less
than the junction area 12 of Fig. 1.

20 As can be appreciated, there are a number of possible
shapes and spacings of subjunctions which will yield a
total junction area having an associated effective
optical area which is substantially equal to a desired
25 optical area, such as the area associated with a
conventional device having a single relatively large,
junction area, while yet providing a reduction in total
junction area.

30 In general, the minimum size of a junction is
determined by the lower limits of photolithography,
photolithography being one widely utilized method of
constructing such junctions. Currently available
photolithographic techniques may be employed to yield

1 subjunctions having a minimum dimension of 1 micron or even less.

5 In accordance with the invention, such a pn-junction comprised of a plurality of smaller subjunctions may have each of the subjunctions conductively coupled together by a layer of metallization which is deposited such that each of the subjunctions is contacted. This aspect of the invention will be described in detail 10 hereinafter.

15 Referring now to Fig. 5 there is shown, in accordance with another embodiment of the invention, a photodiode junction having a reduced surface area which comprises a unitary junction 38 having a smaller junction area than the conventional junction of Fig. 1 while yet providing for a substantially equal optical area 40. As can be seen in Fig. 5, the junction 38 is comprised 20 of a plurality of linear subjunctions 39a-39d interconnected to form a junction having a substantially rectangular outline. The width of each subjunction 39 and the spacing between oppositely disposed subjunctions is predetermined such that the overlap of the optical areas of each of the 25 subjunctions 39 yields an effective optical area 40 which is substantially equal to the desired optical area.

30 Fig. 6 shows yet another junction 42 which is comprised of three linear subjunctions 43a-43c, two of which are similar to the junctions 22a and 22b of Fig. 3, connected together by a third subjunction to form the unitary junction 42. The resulting optical area 44 can

1 be seen to be substantially equal to the optical area
14 of Fig. 1 while the total junction area of the
junction 42 is substantially less than the junction
area of the junction 12 of Fig. 1.

5

It should be realized that a number of different shapes
of junctions may be employed to yield an optical area
having a desired size. Therefore, the invention is not
meant to be limited to only the embodiments shown
10 herein.

Referring now to Fig. 7 there is shown in cross-section
an example of the photodiode 20 of Fig. 3. As can be
seen, the photodiode 20 is comprised of a substrate 46
15 which may be substantially transparent CdTe. Overlying
this substrate layer is a radiation absorbing layer of
HgCdTe which may have a thickness of from 1 to 20
microns. Formed within an upper portion of the layer
48, to a typical depth of 0.5 microns, are the
20 subjunctions 22a and 22b. As can be seen, the layer 48
is doped with a p-type material while the subjunctions
22 are doped with an n-type material.

In the embodiment shown in Fig. 7 the layer 48 may be
25 doped with arsenic or may comprise native acceptors.
The doping concentration of arsenic may be within a
range of from approximately 2×10^{15} to approximately
 5×10^{17} acceptor atoms per cubic centimeter. Each of
the subjunctions 22 may be formed by ion implantation
30 into an upper surface of layer 48 of an n-type donor
material, such as boron, or by implant or other process
damage which is n-type, to a concentration of
approximately 10^{16} to 5×10^{17} atoms per cubic

1 centimeter. The n-type subjunctions 22, instead of being ion implanted, may be diffused into the surface region of the layer 48. Of course, the layer 48 may be doped with an n-type donor material and the 5 subjunctions 22 may be a p-type acceptor material. In either case, the interface between each of the subjunctions 22 and the layer 48 forms a pn-junction, or a diode junction. Overlying the upper surface of the radiation absorbing layer 48 may be a passivation 10 layer 50 comprised of, typically, silicon oxide, native oxides, or a wide bandgap semiconductor such as CdTe or CdS. The passivation layer 50 serves to both electrically insulate the layer 48 and to also control the surface states of the layer 48 to reduce thermal 15 and other noise sources. Formed over the passivation layer 50 is a layer of metallization 52 which is deposited in a conventional manner, such as by evaporation, such that each of the junctions 22 is contacted by the metallization 52. In order to contact 20 each of the junctions 22 a mask may be employed during the formation of the passivation layer 50 such that the passivation layer 50 does not cover the junctions 22. Metallization layer 52 may comprise aluminum, gold or any metal suitable for forming electrical continuity 25 between the junctions 22. In order to interface the junctions 22 to suitable readout circuitry, such as a high speed multiplexer and detector, an indium "bump" may be formed upon the metallization layer 52. The bump 54 has a shape suitable for contacting an 30 overlying conductor (not shown) on a readout device (not shown). Alternatively, metallization layer 52 may be formed to provide a pad for wire bonding the detector to a readout device.

1 It should be pointed out that if a plurality of
physically separated subjunctions are employed, such as
in Fig. 4, the metallization will typically be
deposited such that it conductively contacts each of
5 the subjunctions. If the physically joined
subjunctions are employed, such as in Fig. 5, the
metallization may need to conductively contact only one
point along the subjunction. However, for some
10 junction geometries the series resistance of the
junction may be beneficially reduced by conductively
contacting, with the metallization, one or more of the
subjunctions at a plurality of points.

15 As can be seen in Fig. 7, radiation enters the bottom
surface of the substrate 46, passes through the
substrate 46 and is absorbed within the layer 48
thereby generating photocarriers 56. As can be seen,
photocarriers 56 are collected by the subjunctions 22
both from the volume of radiation absorbing material in
20 layer 48 which is directly beneath the subjunctions and
also from that portion of the layer 48 which is
laterally adjacent to the periphery of the subjunctions
22. Also, photocarriers 56 which are generated in a
region between the two subjunctions 22 are also
25 efficiently collected. Thus, it can be seen that the
optical area 28 of the photodiode 20 has a greater
extent than the area of the subjunctions themselves.
Furthermore, it can be seen by comparing Fig. 7 to Fig.
20 2 that the optical area 28 is substantially equal to
the optical area 14 while yet having a greatly reduced
junction area. This reduction in junction area results
in the aforescribed beneficial reduction in junction
30 capacitance and in the increase in junction impedance.

1 In general, the reduction in junction capacitance
scales in a proportional manner to the reduction in
junction area, however, depending upon the particular
shape of the subjunction chosen, the reduction in
5 capacitance may not be a linear function in that the
perimeter of the subjunction may scale at a lesser rate
than the scaling of the area.

10 Referring to Fig. 8 there is shown a portion of an
array of photodiodes 62 each of which is formed on a
common layer 64 of radiation absorbing material. Such
an array, such as a focal plane array, has individual
photodiodes disposed in an ordered two dimensional
array organized into rows and columns. In accordance
15 with the invention, each of the individual photodiodes
62 has a reduced area pn-junction comprised of a
plurality of subjunctions 66, such as is depicted in
Fig. 4. An active area 68 associated with each set of
20 four subjunctions has an area predetermined for
detecting radiation in accordance with a given
application. Not shown in Fig. 8 is a passivation
layer upon the surface of layer 64 and the
metallization which conductively couples together each
25 group of four subjunctions for coupling each group to a
photodiode multiplexer, detector and readout circuit,
it being understood that the passivation and
metallization layers are similar to that shown in Fig.
7.

30 Although the various embodiments of the present
invention have been described in the context of a
HgCdTe type of photodiode it should be realized that
the use of the invention may be advantageously employed

1 in photodetectors constructed of materials other than
HgCdTe. For example, an indium antimonide (InSb)
photodiode may also advantageously employ the reduced
junction area of the invention. Similarly, other types
5 of radiation detecting materials which are suitable for
forming pn-junctions may also advantageously make use
of the teaching of the invention.

10 Thus, the invention is not to be considered limited to
the embodiments described heretofore and as depicted in
the drawings, the invention is instead meant to be
limited only as defined by the appended claims.

CLAIMS

What is claimed is:

1

1. A photodiode comprising:

5

a layer of radiation absorbing semiconductor material having means responsive to absorbed radiation for generating charge carriers within said layer; and

10

a diode junction formed within a top surface of said layer, said junction collecting said charge carriers for coupling said charge carriers to a detecting means, said junction collecting said charge carriers from at least a portion of said layer surrounding said junction, said surrounding portion defining a photodiode optical area, said junction comprising a plurality of diode subjuncctions disposed relative one to another such that an optical area associated with each of said subjuncctions overlaps an optical area associated with at least one other subjunction for defining said photodiode optical area.

15

20

1 2. A photodiode as defined in Claim 1
wherein said layer is doped with a first type of dopant
and wherein each of said subjunctions is formed by
doping a surface region of said layer with a second
5 type of dopant.

1 3. A photodiode as defined in Claim 2
further comprising a supporting, substantially
transparent substrate underlying said layer.

1 4. A photodiode as defined in Claim 3
wherein said substrate is disposed such that the
radiation enters a surface of said substrate, passes
through said substrate and is absorbed in said layer.

1 5. A photodiode as defined in Claim 4
further comprising:

5 means for insulating said top surface,
said insulating means having openings
made therethrough for exposing said
subjunctions; and

10 means for conductively coupling said
subjunctions to an external circuit
means, said coupling means contacting
said subjunctions through said openings.

1 6. A photodiode as defined in Claim 5
wherein each of said subjunctions are conductively
coupled one to another by being physically joined one
to another.

1 7. A photodiode as defined in Claim 5
wherein each of said subjunctions are conductively
coupled one to another by being contacted by said
coupling means.

1 8. A photodiode as defined in Claim 7
wherein each of said subjunctions has a substantially
circular shape.

1 9. A photodiode as defined in Claim 7
wherein each of said subjunctions has a substantially
elongated bar-like shape.

1 10. A photodiode as defined in Claim 6
wherein at least two of said subjunctions have an
elongated linear shape, each being joined to the other
by a third subjunction.

1 11. A photodiode as defined in Claim 6
wherein each of said subjunctions has an elongated
substantially linear shape, each of said subjunctions
being joined at opposing ends thereof to an end of
5 another of said subjunctions.

1 12. A method of reducing the capacitance of
a photodiode pn-junction, the photodiode having a
predetermined size of an optical area associated with
the lateral collection of charge carriers by a
5 periphery of the junction, comprising the steps of:

 determining the size of the optical
 area;

10 determining the area size of a junction which will provide the determined optical area, the area size of the junction having a first value of junction capacitance associated therewith; and

15 subdividing the determined area of the junction into a plurality of smaller subjunctions having a total area which is less than the determined area, each of the subjunctions having a shape and a spacing therebetween for defining a continuous lateral charge carrier collection area which is substantially equal to the predetermined size of the optical area whereby the sum of the capacitance of each of the subjunctions is equal to a second value of junction capacitance which is less than the first value.

20

25

1 13. A method as defined in Claim 12 further comprising the step of:

conductively coupling each of the subjunctions one to another.

1 14. A method as defined in Claim 13 wherein the step of conductively coupling is accomplished by contacting each of the subjunctions with a common conductor.

1 15. A method as defined in Claim 13 wherein
the step of conductively coupling is accomplished by
physically contacting each of the subjunctions one to
another.

1 16. A photodiode comprising:

 a substrate;

5 a layer of radiation absorbing
semiconductor material overlying said
substrate and being operable for
generating charge carriers from absorbed
radiation, said absorbing layer being
doped with a first type of dopant to a
first concentration;

10 a plurality of regions being doped with
a second type of dopant to a second
concentration formed within a top
surface of said absorbing layer, each of
said regions being disposed relative to
one another for defining a photodetector
diode pn-junction having a total lateral
charge carrier collection area which is
related to the total of the lateral
charge carrier collection areas of each
of said regions;

15 20 an insulating layer overlying said top
surface, said insulating layer having at
least one opening made therethrough for

25

exposing at least one of said plurality of regions; and

a conductor overlying said insulating layer for conductively contacting at least one of said regions through said opening.

1

17. A photodiode as defined in Claim 16 wherein said absorbing layer is comprised of HgCdTe, and said substrate is comprised of CdTe.

1

18. A photodiode as defined in Claim 17 wherein said absorbing layer is doped with arsenic or other p-type dopant or is p-type due to Hg vacancies and wherein each of said doped regions is doped with boron or other n-type dopant or is made n-type by ion implant or other process damage.

1

19. A photodiode as defined in Claim 17 wherein said absorbing layer is doped with boron or other n-type dopant or is made n-type by ion implant or other process damage and wherein each of said doped regions is doped with arsenic or other p-type dopant or is p-type due to Hg vacancies.

1

20. A photodiode as defined in Claim 16 wherein each of said doped regions is physically isolated from said other regions and wherein said conductive layer contacts each of said doped regions for conductively coupling together each of said regions.

1 21. A photodiode as defined in claim 16
wherein each of said doped regions is in physical
contact with each of said other regions.

FIG. 1
PRIOR ART

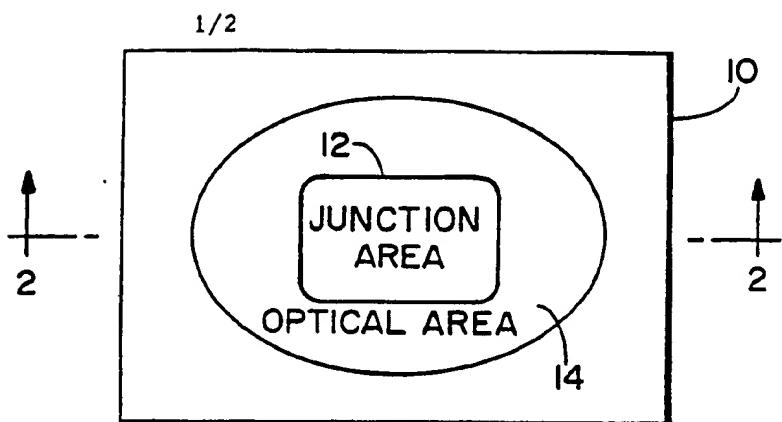


FIG. 2
PRIOR ART

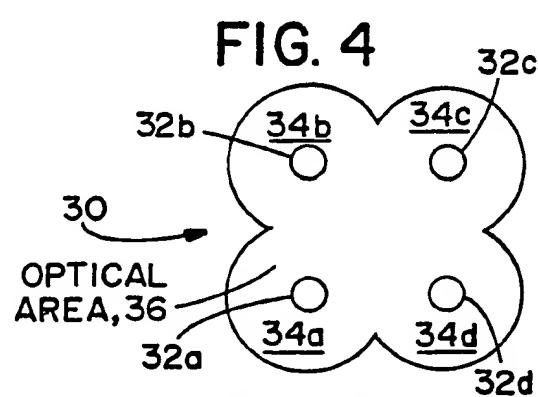
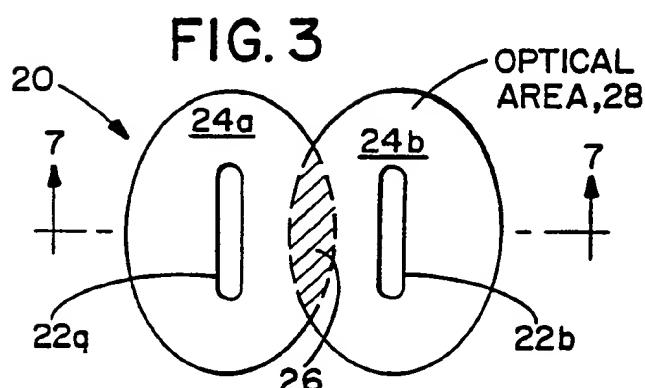
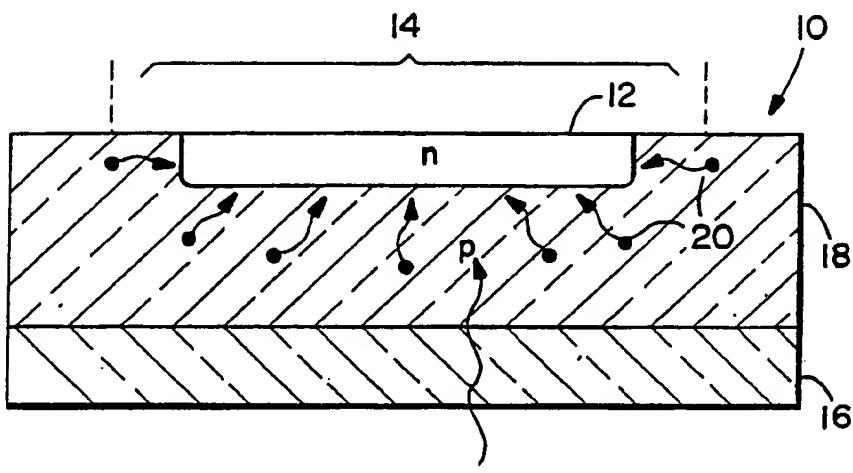
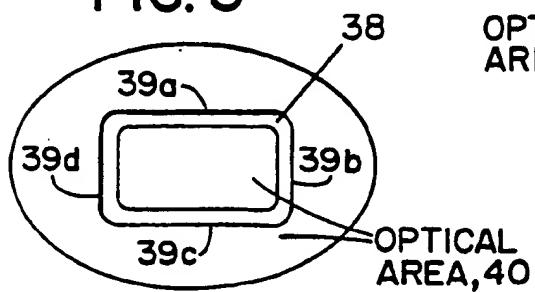
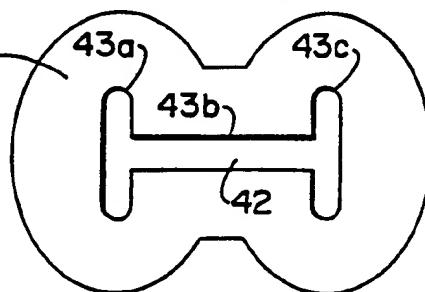


FIG. 5



OPTICAL
AREA, 44

FIG. 6



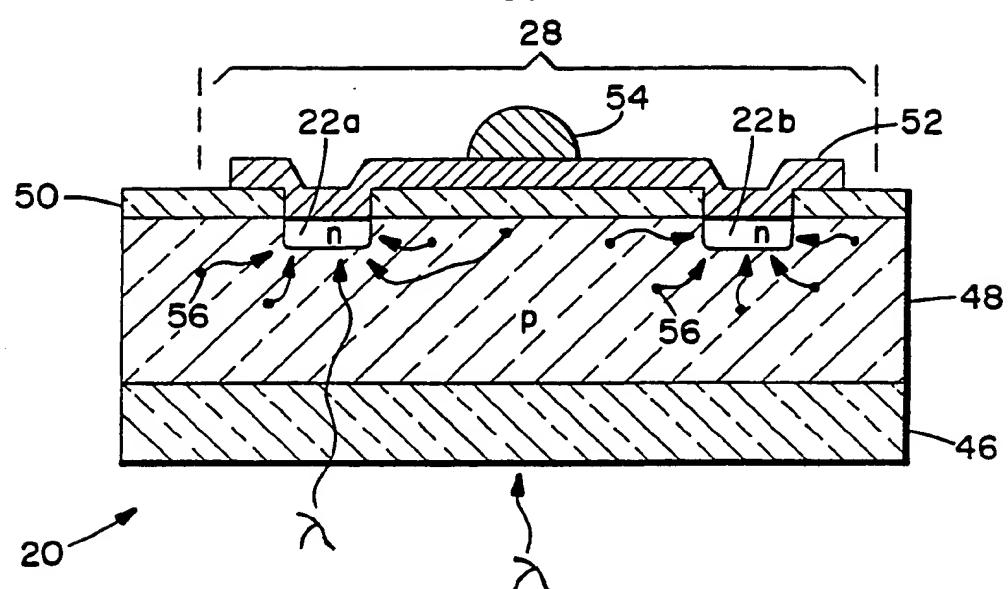
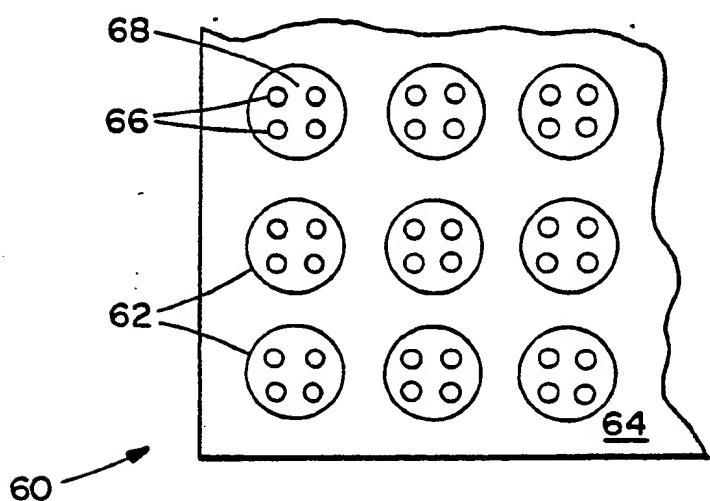
2/2
FIG. 7

FIG. 8



INTERNATIONAL SEARCH REPORT

International Application No. PCT/US 88/03583

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ⁶

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC⁴ : H 01 L 31/02; H 01 L 31/10

II. FIELDS SEARCHED

Minimum Documentation Searched ⁷

| Classification System | Classification Symbols |
|---|------------------------|
| IPC ⁴ | H 01 L |
| Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸ | |

III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹

| Category | Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹² | Relevant to Claim No. ¹³ |
|----------|--|-------------------------------------|
| X | DE, A, 2813671 (FORD-WERKE AG) 12 October 1978, see page 14, line 30 - page 19, line 2; page 20, lines 1-8; page 22, lines 6-29; page 23, line 7 - page 24, line 10; page 24, line 22 - page 25, line 23; page 34, line 28 - page 36, line 25; figures 1a,1b,2a,2b,3a,3b, 6a,6b,6c -- | 1-18,20,21 |
| X | Patent Abstracts of Japan, vol. 8, no. 256, (E-280)(1693) 22 November 1984 & JP, A, 59127883 (MATSUSHITA DENSHI KOGYO K.K.) 23 July 1984, see the whole document -- | 1,2,6,7,9, 10,12-16,20, 21 |
| X | N.T.I.S. Tech Notes, no. 10, Part B, October 1985 (Springfield, Virginia, US) J.T. English: "Solar cells with multiple small junctions", page 1169, see the whole document -- | 1,2,5,7,8, 12,13,14, 16,20 |

¹⁰ Special categories of cited documents:

- ¹¹ "A" document defining the general state of the art which is not considered to be of particular relevance
- ¹² "E" earlier document but published on or after the International filing date
- ¹³ "L" document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- ¹⁴ "O" document referring to an oral disclosure, use, exhibition or other means
- ¹⁵ "P" document published prior to the International filing date but later than the priority date claimed

¹⁶ "T" later document published after the International filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

¹⁷ "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

¹⁸ "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

¹⁹ "A" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search
23rd February 1989

Date of Mailing of this International Search Report

17 72 74

International Searching Authority

EUROPEAN PATENT OFFICE

Signature of Authorized Officer

P.C.G. VAN DER PUTTEN

| III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET) | | |
|--|--|----------------------|
| Category | Citation of Document, with indication, where appropriate, of the relevant passages | Relevant to Claim No |
| X | Patent Abstracts of Japan, vol. 6, no. 176 (E-130)(1054) 10 September 1982 & JP, A, 5792877 (OKI DENKI KOGYO K.K.) 9 June 1982, see the whole document -- | 1,2,5,9,12, 16 |
| A | Nachrichtentechnik Elektronik, vol. 32, no. 3, 1982 (Ost-Berlin, DD) G. Dittmar et al.: "Herstellung von CdHgTe-Infrarotdioden durch Ionenimplantation", pages 108-110. see the whole document | 17-19 |
| ----- | | |

ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.

US 8803583
SA 25481

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 07/03/89. The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---------------------|---------------------------------|----------------------|
| DE-A- 2813671 | 12-10-78 | JP-A- 53123092 GB-A- 1597538 | 27-10-78 09-09-81 |

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